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Actual and Calculated Irrigation Water Requirement of Green Bean Crop under Different Irrigation Systems in Egypt

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Abstract

Drip(DI),subsurface drip(SDI),sprinkler(SPR),and furrow (FUR) irrigation systems were used to determined the actual irrigation water requirements (IR_a)for green bean yield under Egyptian conditions for summer season. In addition there was a comparison between actual irrigation water requirements which determined using the previous methods. Otherwise the comparison between actual and calculated irrigation water requirements (IR_c) and water use efficiency were concedred . The results revealed that : (i) the total IR_a (mm / season) were 224.8, 227.81 , 289.03 and 464.06 for DI,SDI,SPR and FUR respectively , and the percent of the applied water by using DI, SDI , and SPR were 48.44 , 49.01 , 62.28 of that applied by using FUR, (ii) the percent of IR_a determined by using DI , SDI , SPR and FUR were 57.68,53.9,57.3and 74.7 of their calculated irrigation water requirement, (iii) water use efficiency were 3.51 , 4.48, 2.52 and 1.29 kg/m3 for the DI, SDI , SPR and FUR respectively .

keywords: Drip irrigation(DI), Subsurface drip (SDI), Sprinkler(SPR), Furrow irrigation (FUR), Actual irrigation requirements(IR_a) and Calculated irrigation requirements (IR_c)

Introduction

Water becomes most economical scarce resource in many areas of the world, especially in arid and semi-arid regions. However, water is a limiting factor in agriculture expansion depending on its quantity, quality and method of application. Estimating irrigation water requirements becomes more important for project planning and management of irrigation. The primary objective of irrigation is to apply water to maintain crop evapotranspiration (Etc) when precipitation is insufficient and water stored in the soil has been depleted below a level, which decreases crop productivity significantly (Phene et al.1990). Irrigation system and the water requirement corresponding to the maximum yield are considered the most important limiting factors affecting the agriculture production. Improving irrigation systems efficiency, distribution uniformity, and water use efficiency can be achieved when field conditions are considered. Shawky and Sallam (1996) concluded that improving water management in irrigation agricultural areas can not attain sustained optimum land productivity conditions unless a proper soil-crop-water relation are used. This can be achieved through the reliable methods for determining the actual evapotranspiration of different cultivated crops in order to increase the water use efficiency in such arid and semi arid zones.

Farm irrigation system can be classified according to the manner in which water is applied to the soil into four basic methods surface, sprinkler, micro- irrigation and sub surface systems (Rash. 1995).

Hanson et al. (1996) reported that higher bean yields were attained under drip irrigation than under furrow irrigation. Applied water by using the drip irrigation was 44% of that applied by using the furrow system, this differece shows the effect of the low efficiency of the furrow irrigation.

Arnaout (1997) declared that three irrigation system namely drip, sprinkler and furrow irrigation were considered in pea crop to select the most proper system saving ultimate water quantity and producing the highest yield. Also, he found that, the water requirement corresponding to the maximum value of yield (2.625,2.35,2.400 ton/fed) were (1150, 1300 and 1870 m^3/fed) under drip, sprinkler and furrow systems respectively. The main objectives of this work: (i) determine the actual irrigation water requirement (IRa) by using DI, DSI, SPR and FUR systems and compare it, (ii) compare the actual and calculated irrigation water requirement, (iii) select the most successful irrigation systems to apply water through the growth season of bean crop, which produce the highest yield, (IV) calculated the water use efficiency under different irrigation systems.

Materials and Methods

Materials

Experimental site

The Experimental work was carried out during the summer season of 1998 at the Experimental Station Farm, Agricultural Engineering Department, Faculty of Agricultural, Cairo University. A total area of about one feddan was selected.

Irrigation systems layout:

Drip irrigation (DI), subsurface drip irrigation (SDI), sprinkler irrigation (SPR), and furrow irrigation (FUR) systems were installed to investigate the water irrigation requirements for the green bean cultivation. The experimental design and the specification of the irrigation systems installed are show in Fig (1).

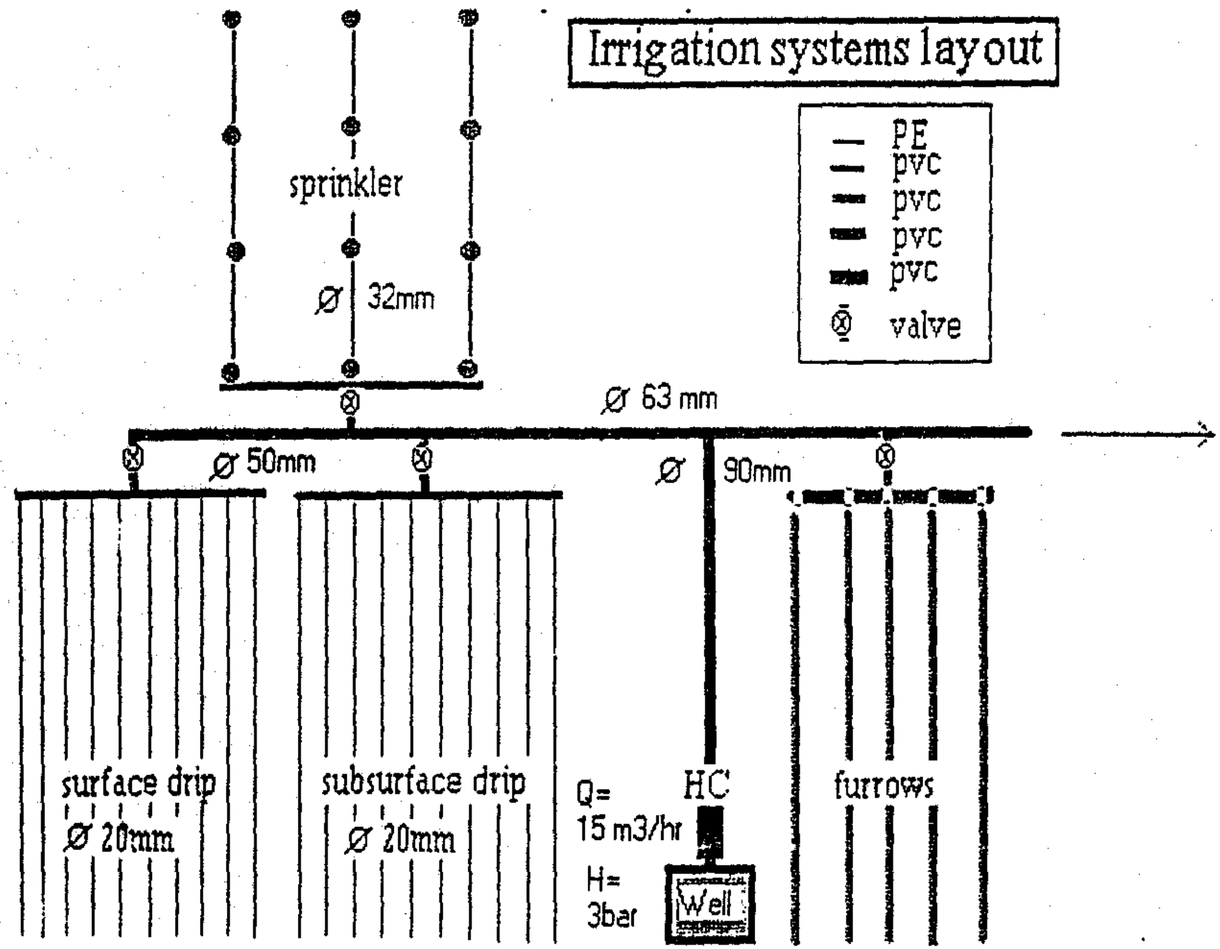


Fig (1) Layout of irrigation Systems in the experimental site.

Irrigation systems evaluation and efficiencies

Irrigation systems evaluation and efficiencies were determined according to Merrian and keller (1978).

Crop cultivation

The bean seeds (phaseolus. Vuig aris- Bronco) were sown on 23/2/1998,as a summer season,on 20 cm planting space and one meter between rows. The common agronomic practices were adapted including the recommended doses of fertilizers(200,200,100kg)per feddan as ammonium sulphate, superphosphate and potassium sulphate, respectively. The fertilizers used were added in two split doses after transplanting and before the flowering stage.

Methods of analysis

Some physical and chemical characteristics of the experimental soil site were determined by using undisturbed and disturbed soil samples collected from two successive soil depths (0-20and 20-40cm).

Physical properties :

- Particle size distribution was determined using pipete method according to Gee and Bauder (1986).
- Bulk density was determined using the core method. Blake and Hartge (1986).
- Field capacity and wilting point were determined using pressure membrane according to Shawky (1967) .
- Infiltration rate was determined using Duble Ring Infiltrometer according to the Herman (1986).

Chemical analyses :

Some chemical analyses for soil water extract (1:2.5) and irrigation water samples were analyzed according to methods described by Jackson (1967) .

Irrigation application and actual irrigation water requirements:

In order to calculate the actual irrigation water requirement, soil moisture content (SMC) was determined daily to reach the depletion level (45% of available water) according to Doorenbos and Kassam (1986). The soil moisture content was determined gravimetrically, for the investigated two soil depths.

The amounts of actual applied irrigation water requirements under each irrigation system was calculated according to James (1988) by using the following equation:

$$IR_a = [((\frac{FC - \theta V}{100}) d) + L F] / E_s$$

where

- **IRa** : total actual irrigation water requirements (mm / irrigation).
- **Fc** : soil moisture content at field capacity on volume basis.(%)
- **θV** : percentage of moisture content at45%depletion of available water (21 % as mean value for the two layer (0-20 and 40 cm) on volume basis).
- **d** : depth of soil layer (cm)
- **LF** : Leaching factor, (10% of IR) According to Ayers and Westcot (1976).
- **Es** : Irrigation system efficiency, %

Calculated irrigation water requirement

The amount of irrigation water requirements was determined using Blaney and Criddle method according to the following equation, FAO (1991):

$$IRc = [((Eto * Kc)\ Dd) + Lf\ ] / Es$$

Where:

- **IRc** : calculated irrigation requirements (mm/interval)
- **Eto** : Potential evapotranspiration mm/day (Blany and Kriddle method)
- **Kc** : crop coefficient (Doorenbos and Kassm, 1986).
- **Dd** : time interval (days)
- **Lf** : leaching factor, 10% (Ayers and Westcot, 1976).
- **Es** : system efficiency,%.

Results and Discussion

Physical and chemical characteristics of the experimental site:

Data presented in table (1) show the particle size distribution, soil bulk density, total porosity as well as available moisture content.

The data indicated that: (i) the two soils layers have the same texture class (sandy loam), (ii) no clear differece between the values of bulk density for the two layers. The values of gravimetric soil moisture content at field capacity, permanent wilting point and available water content indicate that the first layer has a little big available water content than second one. Due to the importance of infiltration process as a term applied to the process of water entry in the soil, the double ring technique was to determine the infiltration rate. The infiltration rate capacity follows the equation:

$$I = 0.28\ t^{-0.45} \qquad (r = -0.49)$$

Where

I : infiltration rate (cm/hr)

t : Lapsed time (minutes)

Accordingly the basic infiltration rate reached to 2.4 cm/h.

Data presented in table (2) concerning the soluble salt, cations and anions content in the experimental soil before cultivation indicates that: (i) the electrical conductivity (ECe 1:2.5) values ranged between 1.92-2.43 ds/cm before caltivation, (ii) dominant soluble cation in the two layers is sodium followed by calcium and magnesium, other wise the dominant soluble anion is sulphate followed by chloride.

Meanwhile at the end of growing season the data presented in table (3) indicates that under surface drip irrigation system there is reduction in the EC values for the two studied layers, while under the sprinkler and furrow irrigation systems are reduction in the Ec value for the upper layer (0- 20 cm) and increasing the EC value for the second layer (20-40cm). Under the sub-surface drip system an increase in the EC values for both layers was observed, this behavior explained that there is a need for leaching the soil at the end of season to reduce the soluble salts in the soil profile. Under the use of subsurface drip system, as expected capillary rises lead to such conclusions.

The data in table (4) show that the electrical conductivity of the irrigation water reach 0.83 ds/cm. On the mean time, it is considered of very low hazard effect, as the SAR value doesn't exceed 0.51 as proposed by Richards (1954).

<u>Irrigation systems evaluation and efficiencies :</u>

Irrigation systems evaluation and efficiencies were determined according to Merrian and Keller (1978) and the results reveal that the application efficiencies of systems were 92.56 %, 92.9%, 81.48% and 65.7% for surface drip, subsurface drip, sprinkler and furrow irrigation systems respectively.

The results indicate that both surface and subsurface drip irrigation systems exhibited approximately the same application efficiency. However the application efficiency under sprinkler irrigation systems was less than the both of drip irrigation systems while the lowest application efficiency was obtained under the furrow irrigation systems.

Table (1) Some physical characteristic of the experimental soil site.

Depth(cm)	Mechanical analyses (%)			Texture class	$CaCO_3$(S)	Soil bulk Density (g/cm^3)	Total soil porosity (% vol)	Available soil moisture Content (% Om)		
	Sand	silt	clay					FC	PWP	WC
0-20	71	15.3	13.7	Sandy loam	4.6	1.5	44.5	17.7	7.5	10.2
20-40	73.2	14.6	12.3	Sandy loam	4.2	1.38	47.9	19.8	11	8.8

Table (2) Total soluble salts and soluble cations and anions in the studied of soil layers (before cultivation)

			Cations meq/L				Anions meq/L		
Deph cm	**pH**	**EC ds/m**	**Ca^{++}**	**Mg^{+}**	**Na^{+}**	**K^{+}**	**HCO_3^- & $CO_3^{=}$**	**CL^-**	**$so_4^{=}$**
0-20	7.74	2.43	7.80	6.40	9.10	1.14	1.00	3.60	19.84
20-40	7.69	1.92	5.60	5.40	7.98	0.82	0.90	3.00	15.90

Table (3) Total soluble salts and soluble cations and anions in the experimental soil site (at the end of experiment) under different irrigation systems

			Cations meq/L				Anions meq/L		
Depth cm	**pH**	**EC ds/m**	**Ca^{++}**	**Mg^{+}**	**Na^{+}**	**K^{+}**	**HCO_3^- & $CO_3^{=}$**	**CL^-**	**$so_4^{=}$**
Surface drip									
0-20	8.23	1.12	2.00	4.10	4.60	0.05	3.40	3.00	4.35
20-40	8.25	1.06	3.00	2.50	3.00	0.05	2.10	2.00	4.45
Sub-surface drip									
0-20	8.16	3.17	14.00	11.00	8.10	0.15	1.50	10.60	21.15
20-40	8.03	3.15	14.80	10.80	7.50	0.14	1.40	9.60	22.24
Sprinkler									
0-20	8.17	2.37	10.50	7.50	6.80	0.12	1.50	5.00	18.42
20-40	8.07	2.95	13.20	9.80	10.30	0.11	1.10	7.60	24.71
Furrow									
0-20	8.15	1.90	6.00	7.80	5.50	0.10	1.30	3.00	15.10
20-40	8.18	2.14	6.60	9.50	6.00	0.09	1.30	6.00	14.89

Table (4) Total soluble salts and soluble cations and anions for irrigation water source (well water)

pH	**EC**	**Cations meq/L**				**Anions meq/L**			
	Ds/m	**Ca^{++}**	**Mg^{+}**	**Na^{+}**	**K^{+}**	**HCO_3^- & $CO_3^{=}$**	**CL^-**	**$so_4^{=}$**	**SAR**
7.20	0.83	3.60	2.60	0.90	0.18	5.00	1.00	1.28	0.51

Irrigation water requirements:

The actual (IRa) and calculated (IRc) irrigation water requirements for the green bean under different irrigation systems are presented in table (5) and illustrated in figs(2a, b, c,d). It is clear from the data that , (i) the calculated irrigation requirements (IRc) was lower than the actual irrigation requirements in the initial stage (Feb-Mar) and this different was clear under furrow irrigation system this is due to the fact that under furrow irrigation and when the irrigation started water was lost by deep percolation and the flooding all soil surface exceeds the evaporation from the bare soil, other wise the crop coefficient (kc) for this stage ranged between 0.3-0.4 so the (Irc) values will reduced, (ii) during the development, mid, and late stages there was opposite behaviour in which the IR_c was higher than IR_a this different between the two values start to increase gradually with crop development stage and the maximum different exists in the mid and late stages in which the kc values was at maximum reached to 0.75 , 1.05 and 0.95 for development , mid and late stages respectively , other wise the IRc value calculated according to irrigation treatment under non restricting soil condition including soil water,(iii)the percent of total IRa determined under DI,SDI,SOR and FUR were 57.68 , 53.9 , 57.3 and 74.7 of their calculated irrigation water requirements, for that the calculated irrigation requirements (Blaney and Criddle) needs much water than the actual irrigation water requirements. Fig(3) presented the actual irrigation requirements under different irrigation systems during the bean growth season. It is clear from the data that the lowest difference in IRa was between DI and SDI irrigation systems. There are a simillar results were obtained between the IRa determined using sprinkler system and the IRa determined using both DI and SDI systems during all stages. On the other hand, the IRa under furrow irrigation has biggest values during all the stages this behaviour returne to the differences between the irrigation efficiency for each system. Moreover, the data explained that the peak of actual irrigation requirement was reached during April month (mid season) in which the plants in the podfill growth stage. Fig (4) explained that the peak period of green bean was in April, and the total IRa mm/month during the peak were 121.4, 112,25,132.64 and 213.2 for DI,SDI,SPR and FUR respectively. Fig (5) also illustrate the total irrigation water requirement mm/season. The data explained that total IRa mm/season were 224.8,227.81,289.03 and 464.06 for DI, SDI, SPR and FUR, respectively. It is clear from the data that the percent of applied water by suing DI, SDI and SPR were 48.44,49.09, 62.28 of that applied by using furrow system this is due to the water application efficiency under each system.

Table (5) Monthly actual and calculated Irrigation water requirements for green bean under different Irrigation system (Summer season).

Month	Irrigation System: Drip irrigation(DI)				Subsurface drip(SDI)				Sprinkler (SPR)				Furrow(FUR)			
	IRa		IRc		IRa		IRc		IRa		IRc		IRa		IRc	
	mm/mon.	mm/d	mm/mon.	mm/d	mm/mon.	mm/d	mm/mon.	mm/d	mm/mon.	mm/d	mm/mon.	mm/d	mm/mon.	mm/d	mm/mon.	mm/d
Feb.6day	11.22	1.87	8.58	1.43	11.16	1.86	8.52	1.42	14.58	2.43	9.72	1.62	25.32	4.22	12.42	2.07
Mar.31day	70.99	2.29	126.17	4.07	70.68	2.28	122.45	3.95	90.83	2.93	158.03	5.13	167.4	5.4	185.69	5.99
Apr.30day	121.2	4.04	214.2	7.14	112.2	3.74	217.2	7.24	132.6	4.42	241.8	8.06	213	7.1	320.7	10.69
May Differ.days	21 (7day)	3	40.81	5.83	33.53 (11day)	3.05	74.29	6.75	51 (14day)	3.64	94.18	6.73	58.02 (12day)	4.83	101.85	8.48
Total IRa&IRc	224.8		389.73		227.81		422.23		285.03		504.63		464.06		621.04	
Yield kg/fed	3315				4291				3060				2718			
Total IRa m	944.16				956.8				1213				1949.05			
WUE kg/m	3.51				4.48				2.52				1.39			
Growing season days	74 days				78 days				81 days				79 days			

Fig (2a): Actual and calculated irrigation requirement under drip irrigation system.

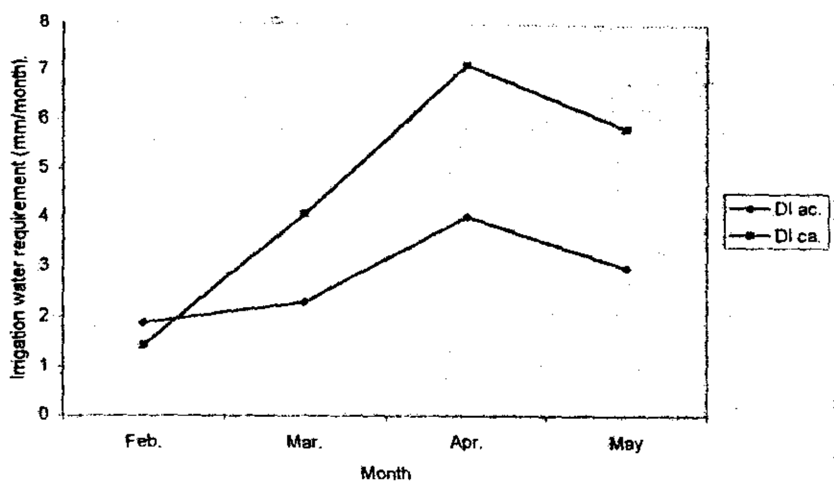
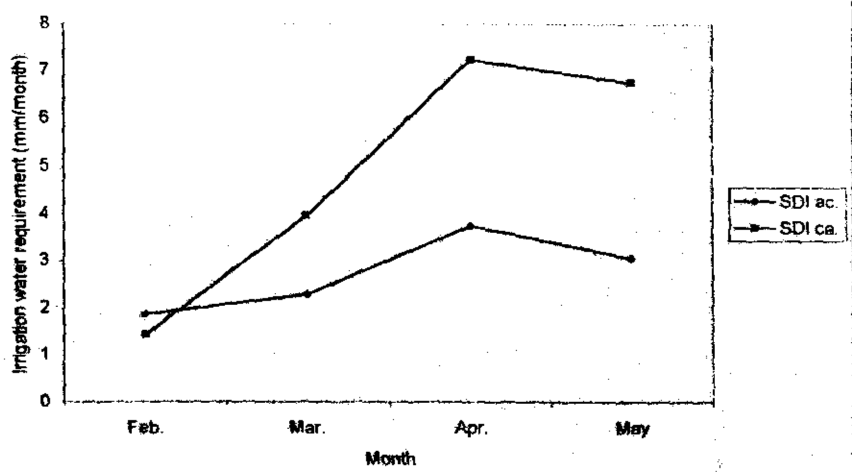


Fig (2b): Actual and calculated irrigation requirement under subsuface drip irrigation system.



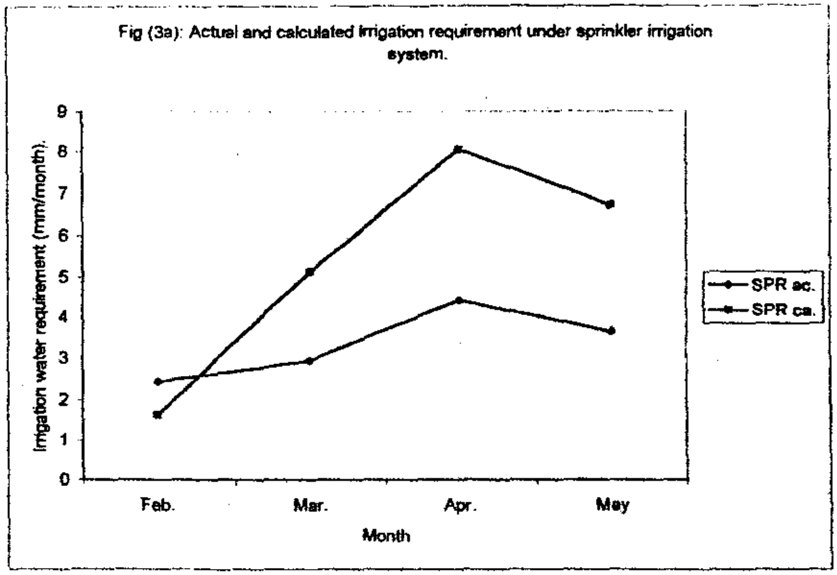


Fig (3a): Actual and calculated irrigation requirement under sprinkler irrigation system.
Irrigation water requirement (mm/month).
9
8
7
6
5
4
3
2
1
0
Feb.
Mar.
Apr.
May
Month
SPR ac.
SPR ca.

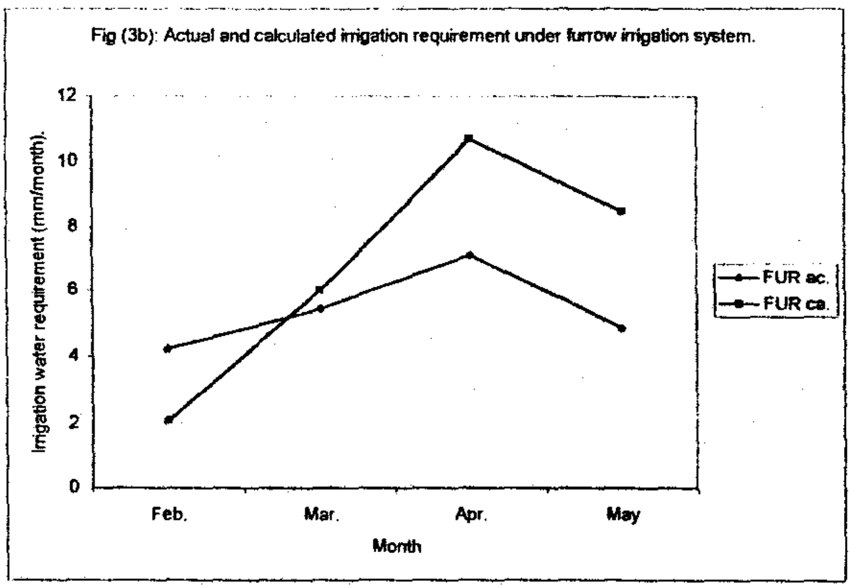


Fig (3b): Actual and calculated irrigation requirement under furrow irrigation system.
Irrigation water requirement (mm/month).
12
10
8
6
4
2
0
Feb.
Mar.
Apr.
May
Month
FUR ac.
FUR ca.

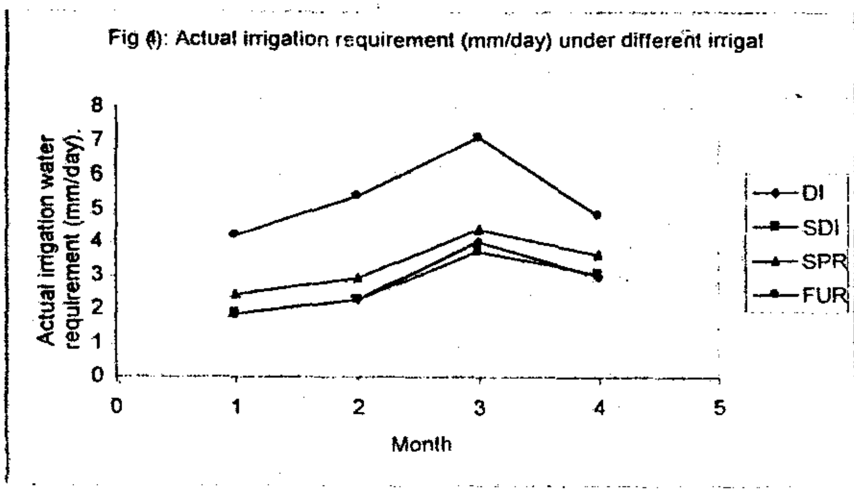


Fig (4): Actual irrigation requirement (mm/day) under different irrigat
Actual irrigation water requirement (mm/day).
0
1
2
3
4
5
6
7
8
0
1
2
3
4
5
Month
DI
SDI
SPR
FUR

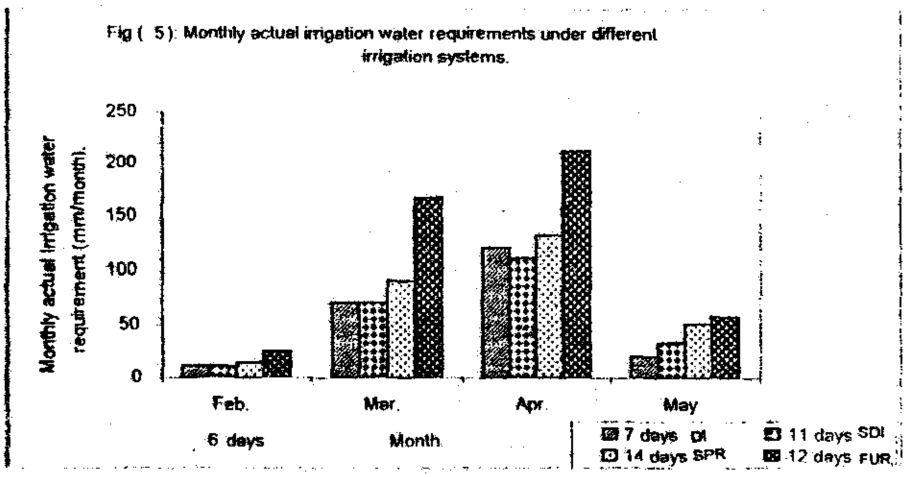
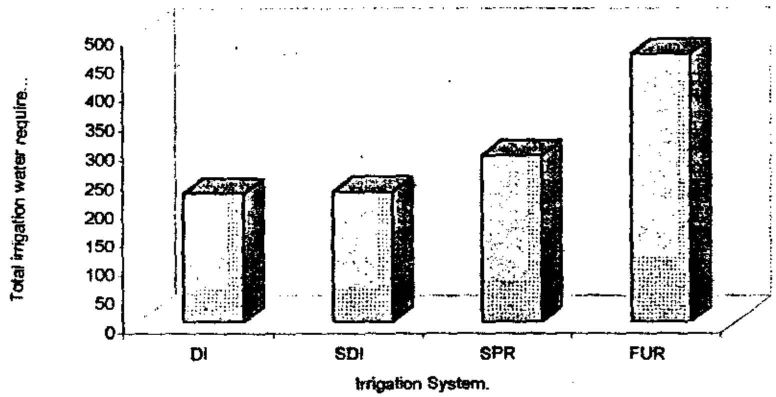


Fig (5): Monthly actual irrigation water requirements under different irrigation systems.
Monthly actual irrigation water requirement (mm/month).
0
50
100
150
200
250
Feb.
Mar.
Apr.
May
6 days
Month
7 days DI
11 days SDI
14 days SPR
12 days FUR

Fig (6): Total actual irrigation water requirements (mm/season) under different irrigation systems.



Yield and water use efficiency:

The yield of summer bean under different irrigation systems are reported in table (5). The data explain that (i) the total yield reaches 3.315,4.291,3.060,and 2.718 ton/fed under surface drip, subsurface drip , sprinkler and furrow irrigation systems , respectively. The analysis of variance was carried out and the value of low significant test explained that there are highly significant differences in bean yield between the different irrigation systems. Also, the data in table (5) explained that the IRa m^3. Were 944.16,956.8,1213.9 and 1949.05 for DI, SDI, SPR and FUR respectively. Accordingly water use efficiency were 3.51,4.48,2.52 and 1.39 kg/m^3 for DI, SDI, SPR and FUR irrigation systems, respectively. These results indicate that the values of water use efficiency (WUE) decrease under irrigation systems in which the amounts of irrigation water requirement increase. On the other hand, the highest yield green bean is produced under irrigation system that has high application efficiency and less application rate and irrigation water requirements.

Conclusion

From the obtained results we can concluded the following.

1- The total calculated irrigation water requirements which determined using Blaney Criddle equation was higher than the total actual irrigation water requirements.

2- Both surface and subsurface drip saved 22.2, 21.17% of the irrigation water requirement comparing with sprinkler system and saved 51.55, 50.90% when comparing with furrow irrigation system.
3- The highest yield of green bean was obtained under subsurface drip and surface drip followed by sprinkler and furrow systems.
4- The highest water use efficiency was obtained under subsurface drip followed by surface drip, sprinkler and furrow systems.
5- The main disadvantage of subsurface drip irrigation system is increasing the soluble salts for the two upper soil layers at the end of growing season, so the soil profile needs to be leached to reduce the level of soluble salts again.

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الملخص العربى

" تقدير احتياجات الري الفعلية والمحسوبة
لمحصول الفاصوليا الخضراء تحت أنظمة ري مختلفة في مصر"

محمد عصام الدين شوقي * ، فتحي عبد الحليم جمعه * ، جمعه عبد ربه بكير ** مصطفي عبده سعيد *

أجريت هذه الدراسة بهدف تقدير الاحتياجات المائية لمحصول الفاصوليا الخضراء صنف **(Phaseolus vuigaris-Bronco)** وذلك للموسم الصيفي (١٩٩٨) بتربة رملية طميية تحت أربعة نظم ري مختلفة هي التنقيط السطحي والتحت سطحي والرش والخطوط· وقد تم تنفيذ هذه التجربة في المزرعة التابعة لكلية الزراعة - جامعة القاهرة علي النحو التالي لدراسة:

- دراسة بعض الخصائص الطبيعية والكيمائية لأرض التجربة وكذلك مصدر مياه الري ·
- تقييم أنظمة الري المختلفة وتقدير كفاءتها ·
- تقدير احتياجات الري الفعلية علي أساس جدولة الري عند استنزاف ٤٥% من الماء المتاح في التربة تحت أنظمة الري المختلفة السابق ذكرها ·
- تم حساب احتياجات الري النظرية باستخدام البيانات المناخية من مركز المناخ الزراعي بالدقي وتم حسابها علي أساس استخدام معادلة بلاني - كريدل·
- تم حساب كفاءة استخدام المياه تحت أنظمة الري المختلفة ·

ويمكن تلخيص أهم النتائج فيما يلي :

١- بلغت كفاءة أنظمة الري المستخدم ٥ر٩٢% ، ٩٣% ، ٥ر٨١% ، ٧ر٦٥% لكل من نظام الري بالتنقيط السطحي ، والتحت سطحي ، والرش ، والخطوط علي التوالي ·

٢- بلغت احتياجات الري الفعلية والمقدرة تحت أنظمة التنقيط سطحي ، التنقيط تحت سطحي ، الرش ، الخطوط ٨ر٢٢٤ ، ٨١ر٢٢٧ ، ٠٣ر٢٨٩ ، ٠٦ر٤٦٤ (مم / موسم) علي التوالي - بينما بلغت احتياجات الري النظرية ٧٣ر٣٨٩ ، ٢٣ر٤٢٢ ، ٦٣ر٥٠٤ ، ٠٤ر٦٢١مم / موسم علي التوالي ·

٣- بلغت نسبة احتياجات الري الفعلية تحت أنظمة التنقيط السطحي ، تنقيط تحت سطحي ، الرش حوالي ٤٤ر٤٨ ، ٩٠ر٤٩ ، ٢٨ر٦٢% من احتياجات الري الفعلية تحت نظام الري بالخطوط.
٤- بلغت نسبة الاحتياجات الفعلية تحت الأنظمة المختلفة تنقيط سطحي ، تنقيط تحت سطحي ، رش ، خطوط ٦٨ر٥٧ ، ٩ر٥٣ ، ٣ر٥٧ ، ٧ر٧٤ % من الاحتياجات النظرية المحسوبة علي التوالي .
٥- كانت أعلي كفاءة لاستخدام المياه تحت نظام الري بالتنقيط التحت سطحي ثم السطحي ثم الرش ثم الخطوط .
٦- أعلي إنتاج للمحصول كان تحت نظام تنقيط تحت سطحي ، ثم التنقيط السطحي ، ثم الرش ،ثم الخطوط .
٧- كل من الري بالتنقيط السطحي والتحت سطحي يوفر حوالي ٢ر٢٢ - ٨ر٢١% من احتياجات الري الفعلية بالمقارنة بالري بالرش وحوالي ٥٥ر٥١ - ٩٠ر٥٠ % عند المقارنة بطريقة الري بالخطوط .

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